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THE DUNE SUCCESSION AT CORNER INLET, VICTORIA

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Summary

1 This paper outlines the physiography of two of the islands in Corner Inlet, Victoria—Sunday I. and Clonmel.

2 Four land types are distinguished—dune ridges, sandy terraces, salt swamp and freshwater swamp.

3 The zonation of the vegetation and soils on the dune ridges of Clonmel and Sunday I. is described; the evidence is presented for regarding the five major zones as stages in primary plant succession on new terrain.

4 Extensive wooded terraces on sandy soils are not considered as stages in the primary dune succession; the origin of the terraces is ascribed to the emergence of unvegetated sand flats formed on the northern coasts of the dune ridges.

5 The vegetation and soil of small areas of damp heath woodland are also described and the origin of this community is discussed.

Physiography

Much of the coast of E. Victoria is bordered by systems of parallel dune ridges at the back of sandy beaches. It is generally believed that such dunes are formed successively on a shoreline advancing seaward by sand accumulation. Sand derived from the sea floor, from eroded coasts or from material carried into the sea by wind or rivers is delivered to the shoreline by wave action, and built into parallel foredunes by the combined effects of wind and dune vegetation. Davies (1957) has emphasized the difference between the constructive action of flat ocean swell, which moves sand up on to the beach, and the destructive action of steep storm waves, which withdraw sand from the beach and carry it offshore. This alternation of constructive and destructive wave action has been termed 'cut and fill' by American geomorphologists. When 'fill' exceeds 'cut', sand is built into a bank or berm (Pl. IV, fig. 1, 2) along the length of the beach, but this is often cut away by storm waves. Eventually, as more sand is deposited on the shoreline, a berm may survive as a permanent feature colonized by dune grasses, which tend to trap sand blown up the beach by onshore winds. In this way, a foredune is built along the back of the beach, and will continue to grow until a newer foredune cuts off the supply of wind-blown sand. Dune grasses are then succeeded by shrubs and trees, and the parallel dune ridges are stabilized. At any stage vegetated dunes may be eroded by wave action or by wind (blow-outs). In Victoria there is evidence that over the last 40 or 50 years many dune systems have been cut back by storm waves, and good examples of embryonic dunes are infrequent in the Port Phillip and Western Port areas.

The dune succession has been studied on Clonmel and Sunday I., two of the group of barrier islands at the mouth of Corner Inlet, a large shallow marine embayment NE. of Wilson's Promontory (Fig. 1). Sunday I. is 5 m. in length

from E. to W. and 2 m. in breadth. It is separated from the mainland near Port Albert by a strait 3 m. broad at high tide.

The island has a central tract of sand ridges running from E. to W., almost encircled by swamps and salt marshes; on the SE. corner there is a smaller sand-ridge tract known as the Drum, and further to the SE. lies Clonmel, an island at the SW. termination of the Ninety Mile Beach (Fig. 1). The sand ridges rise to

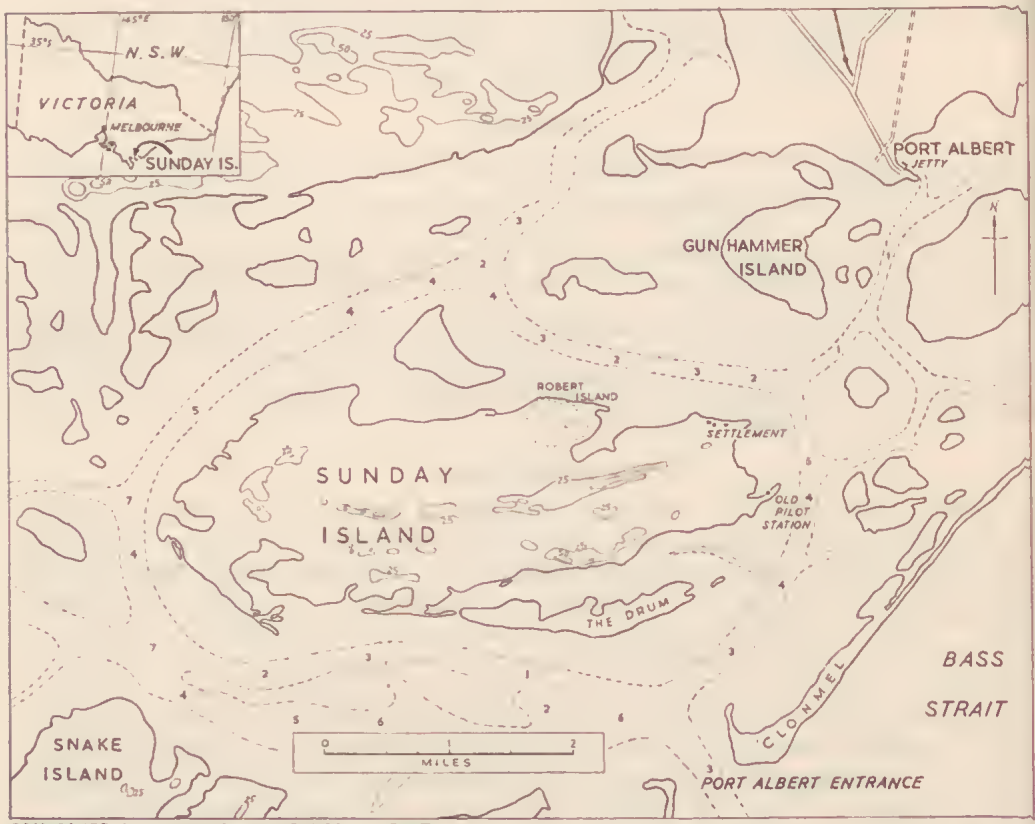

Fig. 1—Map of part of Corner Inlet, Victoria, showing Sunday I., the Drum and Clonmel; based on military maps and Admiralty charts.

between 20 and 60 ft above sea level, and form a complex pattern indicating several stages of foredune formation interrupted by erosion of the shoreline. These foredunes were undoubtedly formed by the processes previously described, and their complex pattern indicates changes in the pattern of waves entering Corner Inlet that were probably due to changes in coastal and offshore configuration in Recent times.

A thorough study of the geomorphology of Cornet Inlet has not yet been made, but the present field survey, coupled with the inspection of aerial photographs, has led to the following conclusions.

Sunday I. is a compound barrier island developed off the estuaries of the

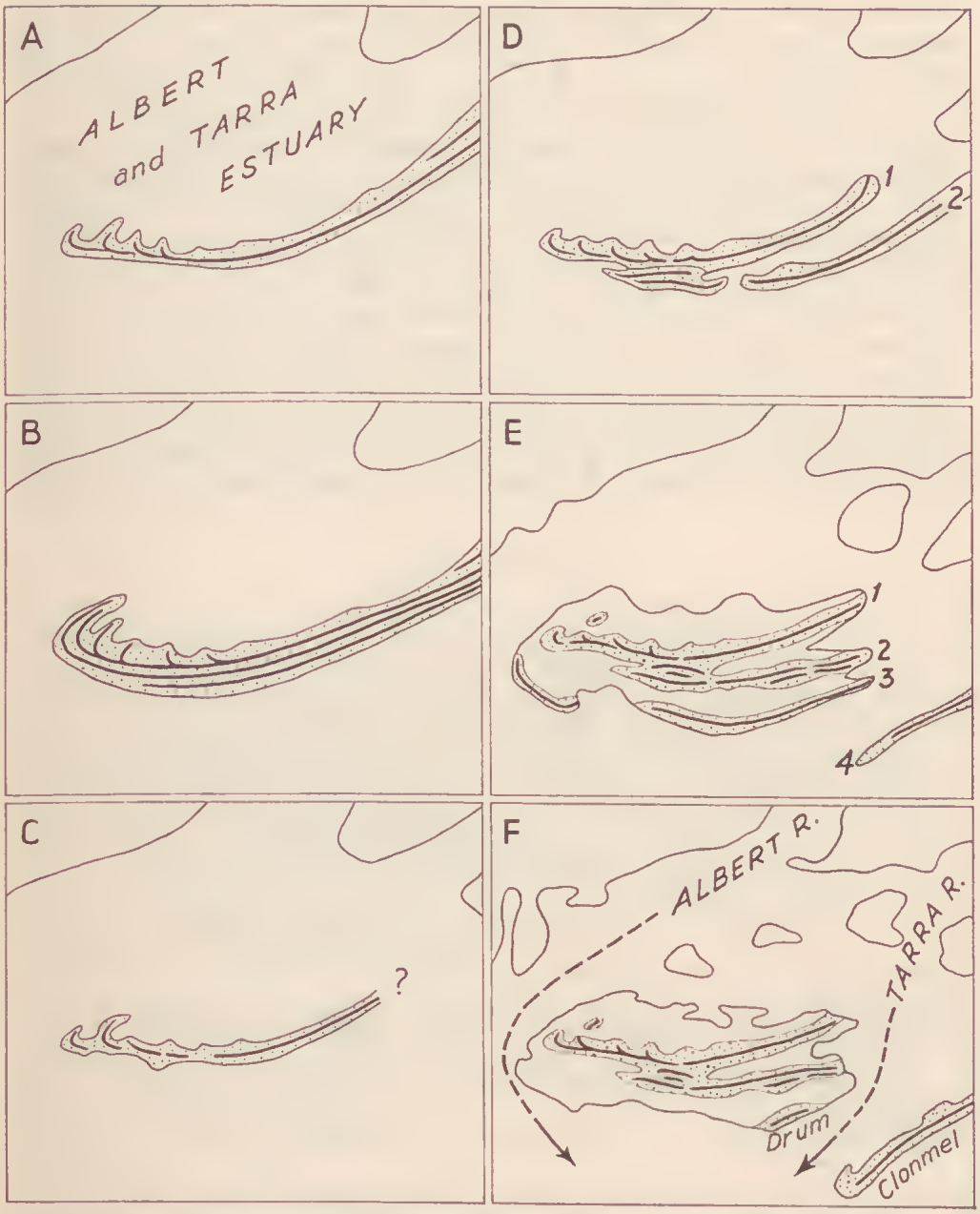

Fig. 2—The evolution of Sunday I., in terms of the successive growth of the coastal barrier at the SW. end of the Ninety Mile Beach and its successive dissection by tidal channels at the mouths of the Albert and Tarra estuaries.

A .... early stage recurved spit
B .... widened coastal barrier
C .... erosion and dissection
D .... second stage recurved spit
E .... emergence and third stage spit
F .... present pattern

Albert and Tarra R., and the main sequence of development is indicated diagrammatically in Fig. 2. It is probable that the evolution of this island post-dates the general submergence of the coast by the world-wide Postglacial marine transgression, and tectonic subsidence of the land has almost certainly occurred around Corner Inlet. The Albert and Tarra valleys were partly drowned by the submergence to form estuaries and a recurved spit developed soon afterwards, partly separating them from the sea (Fig. 2A). This was widened and lengthened, and parallel foredunes developed on it (Fig. 2B), but then wave conditions changed, perhaps as the result of submergence or subsidence, and the spit was eroded and dissected (Fig. 2C). A newer spit was then formed in front of it, and an eroded embayment was filled with newer foredunes (Fig. 2D). At this stage, the adjacent waters must have been shallow, with sandflats exposed at low tide. Later, an emergence, due either to an uplift of the land or a drop in sea level, exposed the adjacent sandflats to form sandy terraces, and led to the formation of newer spits on the seaward side (Fig. 2E). The outline of the barrier island has since been modified by wave action, by the scouring effects of tidal currents in the estuaries, and by the evolution of bordering salt marshes and mangrove swamps. The range of spring tides at Port Albert is 8 ft. Strong tidal currents develop in the estuaries,

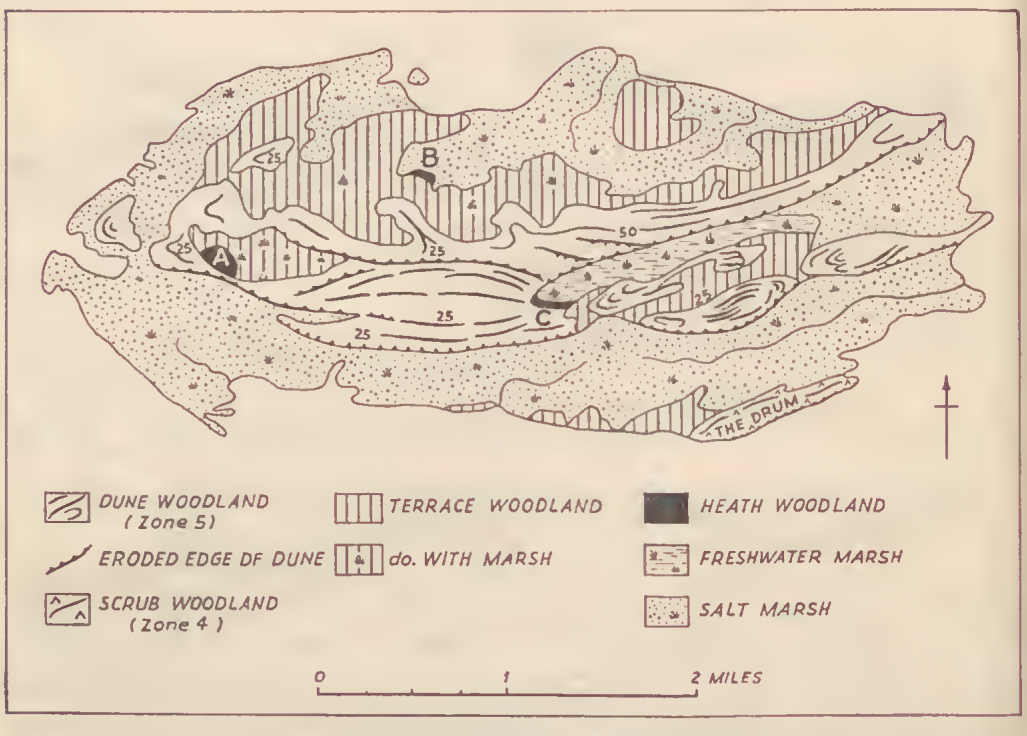

Fig. 3—The major land types on Sunday I., based on ground surveys and aerial photographs.
(1) dune ridges, shown as dune woodland and scrub woodland
(2) sandy terraces, shown as terrace woodland with or without marsh
(3) salt marshes and (4) freshwater marshes
(5) heath woodland, whose origin is discussed in the text.

and at low tide extensive sandflats and mudflats are laid bare on the borders of the island and on the landward side of Clonmel. There has been further growth of the outer spit at Clonmel.

Sunday I. and Clonmel comprise four well-defined land types (Fig. 3). The oldest dune ridges are in the centre of Sunday I.; the 'Drum' is part of a younger ridge and Clonmel bears dune ridges in the course of formation. On Sunday I., eroded dune cliffs occur on the NE. and SE. shores and steep slopes, marking the position of eroded dune cliffs formed earlier (when 'cut' exceeded 'fill'), are traceable in the dune ridge country. The sandy terraces on the landward side of each set of dune ridges are presumed to be old sandflats, exposed by emergence or by a fall in sea level. Salt marshes have formed in the sheltered marginal areas between the dune ridges and on the inland coasts of Sunday I. Other low-lying areas enclosed by or adjacent to sand ridges inland have developed as extensive freshwater marshes as a result of the seepage of rain water from the dunes.

The islands of Cornet Inlet are geologically of Recent formation. In this paper we describe 5 distinct zones of vegetation on the dune ridges and give the evidence for the view that these represent 5 stages of primary plant succession on new terrain. We also deal briefly with 2 other communities on sandy soils, terrace woodland and heath woodland, and discuss their origin.

Recent History

The open country of the mainland, behind Port Albert, was settled and stocked by 1844, and Sunday I. has been used for grazing since at least 1860. A small pilot station was inhabited from 1900-1922, and a homestead was occupied from 1918-1938. At first the grazing was by cattle, some 350 head, but later the island became a sheep run, carrying as many as 2,200 animals at any one time. A small area of the N. terrace was planted to *Acacia* (for tan dark) *circa* 1938, and from that time to 1950 the island was grazed mainly by wallabies and by rabbits which have been abundant for 50 years. Goats were introduced in 1928, and a few still ran wild on the S. marshes in 1947. Wallabies and goats were exterminated by dogs in 1950, when the rabbit population was also greatly reduced by the spread of myxomatosis from the mainland. In 1950 more intensive sheep farming was initiated. The application of superphosphate and the introduction of pasture species will cause considerable local changes in the vegetation.

Most of the grazing was undoubtedly in the freshwater swamps, on the damper parts of the terrace woodland and on the salt marshes. The plant communities of the sand ridges and hollows still appear to be in a natural state. They carry some 126 of the total 254 vascular plants recorded for the island. Of this total, 32 are aliens, but the majority of these are found mainly on terrace woodland near the settlement. Only 6 alien species were recorded for dune woodland (Table 2), and the 8 aliens in the younger stages of the dune sere are clearly of no ecological significance.

Occasional fires have been reported over the period 1908-1949. They have caused no serious damage to the standing trees, but may have modified the nature of the ground flora—in particular by encouraging the growth of bracken in dune and terrace woodland. There is no field evidence to suggest that fire has been an important factor in modifying succession.

The present vegetation has been developed in a mild, maritime climate (in Thornthwaite's (1948) Symbols, $B_1, B^1/B^1_2, S, a^1$).

Stage of sore—Zone	1	2	3	4	5	–
Species	Embryonic dune Clonmel	Fore dune Clonmel	Dune scrub Clonmel	Old Dune scrub The Drum	Duno woodland Sunday I.	Heath woodland Sunday I.
Drosera planchonii				+	+	+
Eucalyptus viminalis				+	+	Co-Dom.
Gahnia radula				+	+	
Galium propinquum				+	+	
Geranium pilosum				+	+	
Glycine clandestina				+	+	
Goodenia ovata				+	+	
Kennedya prostrata				+	+	+
Lepidosperma concavum				+	++	+
L. elatius				+		
Lindsaya linearis				+	+	
Luzula campestris				+	+	
Pterostylis pedunculata				+	+	
Schizaea bifida				+	+	+
Spyridium parvifolium				+	+	
Stylidium graminifolium				+	+	
Themeda australis				+	+	
57 species listed in Table 2					+(57)	
Acacia verticillata					+	++
Acrotriche serrulata					+	++
Astroloma humifusum					+	++
Banksia serrata					Co-Dom.	Co-Dom.
Calorophus lateriflora					+	+
Danthonia semiannularis					+	+
Epacris impressa					+	+
Euphrasia collina					+	+
Halorrhagis teucrioides					+	+
Hibbertia acicularis					+	+
Imperata cylindrica					+	+
Lagenophora stipitata					+	+
Leptospermum juniperinum					+	+
Leucopogon virgatus					+	+
Lomandra longifolia					+	+
Monotoca scoparia					+	+
Pteridium esculentum					++	(+)
Wahlenbergia gracilis agg.					+	+
Xanthorrhoea australis					+	+
X. minor					+	+
Casuarina pusilla						+
Banksia marginata						+
Total No. of species	4	16	22	43	118	30
Zone	1	2	3	4	5	–
Stage of sere	1	2	3	4	5	?6

Total species of dune sere: 141

\+ Present ++ Abundant (+) Rare

Rainfall is not likely to differ appreciably from that of Port Albert, where 70 years of observations give an annual precipitation of 26 in., fairly evenly distributed over the year, but with maxima in spring and autumn and minima in the summer and winter. The rainfall is reliable and the number of days with measurable rain is about 140 per year. The annual maximum of temperature on the island is likely to reach 100°F., the annual minimum 38°F., with 10 days of maximum temperature over 90°F. and only four days with a minimum below 40°.

The Dune Succession

We describe 5 well-defined zones of vegetation on dune ridges, at the same time marshalling the evidence which clearly indicates that these are 5 stages in plant succession (Table 1).

Zone 1. Embryonic dune—Clonmel I.

On the seaward coast of Clonmel long sand ridges lie parallel to the ocean swell. That nearest the sea is the unvegetated 'beach ridge' or 'berm', just above high tide level and with its steeper face inland (Pl. IV, fig. 1, 2). This is clearly formed by sand delivered to the beach by wave action. On its surface occur a few very small embryonic dunes, of wind-blown sand accumulated round the base of plants. Other and larger embryonic dunes occur along the seaward face of the next parallel dune ridge, the fore dune, which is presumed to be built on an earlier berm.

The dominant plant of the Clonmel embryonic dunes, and the chief sand binder, is *Festuca littoralis* (Pl. IV, fig. 1, 2), which takes the place here of *Agropyron junceum* and *Ammophila arenaria* of the English dunes. *Atriplex cinerea* (a shrub up to 4 ft high) and the annual *Senecio lautus* occur occasionally, but play no important part in sand binding. *Cakile maritima* and the introduced *Sonchus asper* are the only other species recorded for this zone, *Cakile*, as in Europe, being really a plant of the drift-line along the foreshore.

The light yellow beach sand in this region is mainly quartz with about 5% $CaCO_3$ and a pH of 7·8. The sand of the embryonic dunes has the same appearance, still contains $CaCO_3$ (2-3%) but is neutral in reaction. There is, however, no true soil formation and the vegetation is largely open and patchy.

Zone 2. Fore dune—Clonmel I. (Pl. IV, fig. 2-4)

The fore dune on Clonmel is a long ridge of sand, up to 25 ft high, parallel to the present beach ridge and clearly formed on an earlier ridge by the coalescence of embryonic dunes, after further accretion of blown sand. The vegetation includes the 4 species of Zone 1 but is less open. Another 13 native species of flowering plant occur. The dominant plant is *Spinifex hirsutus*, a sand-binding grass with a long, creeping rhizome and an efficient method of seed dispersal, the spiny, globular fruiting heads being blown along the sand by the wind until they catch in some obstruction, or break up. The advance of the rhizomes of this grass into embryonic dunes is shown in Pl. IV, fig. 2, 3, 6. The two large shrubs, *Olearia* and *Helichrysum* (Table 1) are clearly invading from Zone 3. 6 of the 8 other species also occur in the neighbouring salt marshes, and although they may help in stabilizing the surface, they are not true dune builders. The following alien weeds were present:—*Rumex pulcher, Silene anglica, Anagallis arvensis, Picris hieracioides.*

On the seaward side of the fore dune the sand between the plants is bare, and its surface layers are still pale yellow and unstabilized; even near the plants themselves there is no free litter or obvious darkening of the surface soil. Near the boundary of Zones 2 and 3, however, the dunes are, in places, becoming stabilized

and the surface may be thickly carpeted with mosses and lichens, of which the major species are *Tortula princeps, Bryum billardieri* and *Cladonia* spp.

Zone 3. Dune scrub on stable dune ridges—Clonmel I.

Parallel to and close to the fore dune and forming the main part of Clonmel I. is a series of roughly parallel dune ridges little higher than the fore dunes, but carrying a closed community of shrubs which cover ridge and hollow (Pl. IV, fig. 4). The ecotone between Zones 2 and 3 is very narrow.

The shrub species which share dominance are *Acacia longifolia* var. *sophorae*, *Olearia axillaris* and *Helichrysum gunnii*. Of these, the last two are occasional in the fore dune. The *Acacia* grows as a fairly erect shrub in the main community, where it resembles a more fleshy and smaller form of the inland *A. longifolia*. On the seaward margin of the scrub it adopts a more creeping habit, with long, decumbent branches sometimes rooting at the nodes and slowly invading the fore dunes. Accompanying these 3 shrubs, but rather less frequent, are *Leptospermum laevigatum, Leucopogon parviflorus, Rhagodia baccata* and, still less frequent, *Myoporum insulare*. These shrubs grow very closely together, reaching an average height of 20-25 ft, and entrance into the scrub is difficult. They cast a dense shade in the swales of the dune where the ground flora is very sparse, but the canopy is more open on the ridges where *Acaena ovina* often covers the ground. In other more open places mosses (*Tortula princeps, Tortella calycina, Bryum billardieri, Ceratodon purpureus, Funaria hygrometrica*) are abundant. Evidence of succession is provided by the persistence of *Spinifex* and *Atriplex* in the community, and also by the presence of dead *Spinifex* shoots. Moreover, the soil is slightly more mature than that of stages 1 and 2, especially in the swales. There is a thin litter of dry leaves and the surface 6″ now has a greyish colour due to the admixture of humus. This layer has a pH of 6·8 and the sand immediately beneath contains 3% $CaCO_3$; there is no true soil profile or podsolization.

The remaining species, all but one of them occasional herbs of little importance, are listed in Table 1. The rare occurrence of one tree, *Banksia integrifolia*, is regarded as an indication of the seral nature of this stage and the possibility of its eventual replacement by scrub woodland of the type found on the Drum, designated as stage 4 of the zonation.

The dune scrub, where it occurs on Clonmel, persists almost to the water's edge on the N. coast of the island. There is, however, a strip of vegetation along a drift-line rich in *Atriplex cinerea* and, with other species of Zone 1, separating the scrub from the open sand. There is clearly no terrace formation on the inner side of this island, but there is an extensive, unvegetated sandflat exposed at low tide, separated from Sunday I. by a deep estuarine channel. This area will be referred to again in the discussion of terrace woodland.

Zone 4. Scrub woodland—the Drum dune ridge

The Drum is the local name of a long, narrow, sandy ridge running parallel to Sunday I. itself and separated from it by wide mudflats with fringing salt marshes, which are inundated at high tide. Here we deal only with the dune ridge, 20-30 ft high and about 50-100 yds wide, on the seaward side of the Drum. N. of this is a narrow flat terrace carrying *Eucalyptus viminalis* and bracken or *Melaleuca* scrub, obviously closely related to the terrace woodland of the main island.

On the S. side of the Drum ridge the dune is considerably eroded and forms

a cliff, 6-15 ft high. No traces remain of any early stages in primary succession on the Drum itself; there are only a few secondary embryonic dunes on the shore below the cliff. The evidence that the Drum dune ridge represents Zone 4 in the succession is provided partly by its position and height, partly by its soil characteristics and mainly by the major woody species of the dune scrub (Table 1). These species also occur in Zones 3 and 5, but more sparingly in both. They are the coastal banksia (*B. integrifolia*), up to 40 ft. high, and 2 smaller species, up to 15-20 ft high, *Leptospermum laevigatum* (the more abundant) and *Leucopogon parviflorus*. *Acacia longifolia* var. *sophorae* (of Zone 3) is rare, *Helichrysum gunnii* (Zone 3) and *Banksia serrata* (Zone 5) are absent. There are a few scattered trees of *Eucalyptus viminalis*, the other co-dominant of Zone 5.

The ground flora of the whole of the Drum ridge is variable, and it is doubtful whether all the species recorded represent those naturally associated with the woody plants already named.

These shrubs and trees arise from an A horizon which is now buried under 2-3 ft of blown sand and it appears therefore that, during the lifetime of the woody species, secondary dune formation has occurred. The nature of this new soil surface and of the plants it bears, therefore, has little relevance to the problem of primary succession. The species listed in Table 1 are those which occur on those parts of the Drum ridge least affected by blown sand, and it will be noted that they include species from both Zones 3 and 5 (Dune woodland). Other species on the Drum dune, some of them aliens (°) are:—*Carpobrotus rossii, Acaena ovina,* °*Sonchus asper* and °*S. oleraceus, Gnaphalium luteo-album,* °*Hypochaeris radicata, Senecio glomeratus,* °*Fumaria officinalis.*

For reasons given above, the soil of the Drum ridge was not fully investigated. It is clear, however, from a study of the original but mostly buried A horizon of Zone 3, that it is a dark layer fairly rich in humus; the soil is rather more mature than that of Zone 3, but shows very little evidence of the podsolization of Zone 5. The sand covering the earlier profile is still calcareous (1·8-3% $CaCO_3$) and alkaline (pH 7·3-7·5). The bryophyte flora is similar to that of Zone 5.

Zone 5. The dune woodland

About one-third of the area of Sunday I. is made up of old stable sand dunes, reaching 50 ft above sea level (but often less) and covered by an open mixed woodland of *Eucalytus viminalis* and *Banksia serrata*. The dunes run approximately E. to W. in ridges, with the steeper sides facing the sea, the ground between the ridges being undulating. The woodland occupies almost the whole of this undulating and ridged area (Fig. 3). The vegetational community is closely similar to that found in the neighbouring coastal regions of the mainland, on similar soils.

E. viminalis, growing to 30-40 ft, often shares dominance with *B. serrata* (30 ft). In some parts of the island these 2 species are present in more or less equal numbers, but there are large areas of dune woodland in which *Banksia* is the more abundant tree. Such variations are not correlated with topography, but may be connected with unequal resistance or exposure to fire, coupled with heavy seeding of one species or one specimen. This is borne out by the fact that, although seedlings of both trees are frequent, they are of local occurrence. There are, for instance, areas of some acres dominated by *Banksia* but very rich in *Eucalyptus* seedlings. Other areas with mixed mature trees are rich in *Banksia* seedlings and

laeking in young *Eucalyptus*. Apparently there has never been a really severe fire on the island, but it has twiee been burnt in part within living memory.

Although from the sea the trees form an apparently solid front of vegetation, thc woodland is actually very open (Pl. V, fig. 1). The crowns very rarely meet, and the shade cast by leaves is very light except directly under the dense *Banksia* crowns. The *E. viminalis* is of the typieal coastal form, with straggling growth and trunks up to 2 ft diameter, with rough, grey bark to the tops of the main branehes. Both the co-dominant tree speeies flower and fruit freely and show little sign ot extensive fire damage.

The distribution of *Banksia integrifolia* on thesc islands is of eonsiderable interest. It oecurs sporadieally in Zone 3 on Clonmel, but it is a eharaeteristic species of thc Drum dune. Hcre it occurs with *Leptospermum laevigatum* and *Leucopogon parviflorus* on stable but very immature soils, as it docs in the more westerly parts of the Vietorian eoast, e.g. at Port Phillip. It is also found in dune woodland on Sunday I., where, howevcr, it has a vcry restrieted and signifieant distribution. It oeeurs in a very narrow strip of the eroded S. eoast dune and there are also a few trees on the seaward eroded edge of thc main island dune ridgc whieh faces the central marsh (Fig. 3). Elsewhere on Sunday I. it is completely absent, its plaee being taken in climax dune woodland by *B. serrata*. It therefore seems probable that the existing trees of *B. integrifolia* on Sunday I. persist as the remnants of an earlier seral stage, rcsembling that of thc Drum ridge. The detailed nature of the soil under these relies has not been investigated, but it is elear that the relationship of *Banksia* species to soil pH is of considerable interest.

Apart from a few exoties on thc old pilot station area, the only other trees on the island are *E. obliqua* (one maturc specimen only, with a nearby seedling) and a small grove of *Acacia melanoxylon* (blackwood). Both of these speeies are regarded as chance introductions from the mainland. The seattered taller shrubs are too few to form a definite shrub layer, exeept loeally where *Acacia suaveolens* forms thickets up to 5 ft high.

The dominant plant of the field layer is *Pteridium esculentum* (Pl. V, fig. 1), although the smaller and less obvious sedge, *Lepidosperma concavum*, is equally frequent and may be regarded as the subdominant. The bracken only rarely forms dense societies, but is fairly evenly distributed over ridge and hollow, with fronds averaging 2-3 ft in height and so spaced as to allow plenty of light to reach the ground. This is very sparsely vegetated in summer with flowering plants. On the NE. side of thc island, subject to strong easterly winds, the soil surface is often bare, and in some parts it is still being slowly raised by the deposition of white blown sand.

The field layer eontains many other speeies of shrubs and herbs, but few of them are frequent except locally. Table 2 gives a list of those speeies encountered on our 3 visits. The general aspeet of the eommunity is determined by thc bracken, and other species provide only a fraetion of the sparse cover. Even in spring, when the orchids and grasses, especially *Aira caryophyllea*, are in leaf and flower, the vegetation is open except in the sheltered aspects of the old dune ridges; here bryophytes and lichens often form a dense carpet. The many local variations in frequency and density of the other speeies may possibly be related to shelter and dispersal, but one particular tendency may be noted; those speeies characteristic of heath or heath woodland (marked *) increase in frequeney towards the W. end of the island, where small patehes of true heath woodland exist.

TABLE 2

Species of the dune woodland (Zone 5)

TREES:

Eucalyptus viminalis, co-dominant
Banksia serrata, co-dominant
B. integrifolia, rare and local

SHRUBS, DWARF WOODY PLANTS, CLIMBERS, PARASITES:

(a) Frequent to occasional—

Acacia longifolia
A. stricta
* *Acrotriche serrulata*
* *Astroloma humifusum*
* *Epacris impressa*
Goodenia ovata
Helichrysum gunnii
Leucopogon ericoides
Leucopogon parviflorus
Monotoca elliptica
M. scoparia
Muehlenbeckia adpressa

(b) Uncommon to rare—

Acacia ulicifolia
Cassinia aculeata
* *Leptospermum juniperium*

(c) *A. Melanoxylon*
(c) *A. mearnsii*
A. verticillata
A. verticillata var. *latifolia*
A. verticillata var. *ovoidea*
Amperea xiphoclada
* *Aotus villosa*
Billardiera scandens
* *Bossiaea cinerea*
* *Bursaria spinosa*
* *B. prostrata*
Bursaria spinosa
Cassytha glabella
Casuarina stricta
Clematis aristata
C. microphylla
Correa reflexa
* *Dillwynia floribunda*
Exocarpus strictus
* *Hibbertia acicularis*
* *H. fasciculata*
* *H. prostrata*
* *H. stricta*
Hakea sericea
* *L. myrsinoides*
* *Leucopogon virgatus*
Myoporum insulare
Phrygilanthus cucalyptifolius
Pimelea linifolia
Platylobium triangulare
Pomaderris aspera
Pultenaea daphnoides
P. gunnii
Rhagodia baccata
Spyridium parvifolium

FIELD LAYER:

(a) Abundant—

Pteridium esculentum, dominant
Lepidosperma concavum, sub-dominant

(b) Frequent to occasional—

Acaena ovina
Acianthus exsertus φ
A. caudatus φ
A. reniformis φ
o *Aira caryophyllea* φ
Burchardia umbellata φ
Caladenia carnea φ
C. latifolia φ
* *Calorophus laterifiora*
Centrolepis strigosa
o *Centaurium minus*
o *Cerastium glomeratum*
Comesperma volubile
Crassula sieberiana
Danthonia semiannularis
Dianella revoluta
Dichondra repens
Dichopogon strictus
Dipodium punctatum
* *Drosera auriculata*
* *D. planchonii* var. *albiflora*
Senecio quadridentatus
Euphrasia collina
Galnia radula
G. filum
Galium propinquum
Geranium pilosum
Gnaphalium involucratum
Hypoxis glabella φ
Halorrhagis tetricioides
o *Hypochaeris radicata*
* *Hypolaena fastigiata*
Helichrysum scorpioides
H. semipapposum
H. gunnii
Imperata cylindrica
Kennedya prostrata
Lagenophora stipitata
Lepidosperma gladiatum
Lomandra filiformis
L. longifolia
Luzula campestris
Marianthus procumbens
o *Oxalis corniculata*
Poa australis
o *Polycarpon tetraphyllu*
Pterostylis alata φ
P. concinna φ
P. curta φ
P. nutans φ
P. pedunculata φ
P. vittata φ
Schizaea bifida
Scirpus nodosus
Spergularia rubra
Stackhousia spathulata
Stylidium graminifolium
Themeda australis
Thysanotus patersonii
Viola hederacea
Wahlenbergia gracilis agg.
* *Xanthorrhoea australis*
* *X. minor*
* *Xanthosia pusilla*

BRYOPHYTA:

Lophocolea heterophylloides
Brachythecium salebrosum
Campylopus introflexus
Ceratodon purpureus
Funaria hygrometrica
Bryum affine
B. pachytheca
Hypnum cupressiforme
Tortella calycina
Scmatophyllum homomallum
Tortula princeps

LICHENS:

Cladonia aggregata
C. Pyxidata
Ramalina calicaris
Usnea barbata

*Species generally more frequent on the W. dune ridges and indicative of the trend to heat
woodland; φ vernal; o alien; (c) casual.

The soil of the dune woodland is a very light quartz sand showing clear but not advanced podsolization (Pl. V, fig. 2). There is some little humus in the top foot or two but no well-defined Ao litter horizon. The surface layers have a pH of 4·5 and the pH range in the profile is from 4·5 to 8·0.

The A horizon varies in depth from 30 in. to 45 in.; it is a light grey sand above, grading to almost pure white below. The B horizon varies from a wide, ill-defined layer of red-ochraceous sand as much as 4 ft thick to a compact, dark brownish-red layer only a few inches thick, but it is never a hard, rocky pan. The horizon is often ill-defined below, extending downwards in long, vertical streaks, where the red colour is often most intense. The C horizon is a pale yellow siliceous sand. No bedrock or calcareous concretions have been found even in pits dug below the water table. Some old stumps with calcareous concretions on their surface are found along the shore line near the settlement, but these have clearly fallen from the eroded edge of the dune and calcification appears to be very recent.

Most of the roots and rhizomes occupy the A2 horizon, but *Pteridium* rhizomes may be found at 2 ft and the roots of *Banksia* and *Eucalyptus* extend to at least 6 ft. Table 3 presents some data illustrating podsolization in these sandy soils.

TABLE 3

Profile in deep sand; eroded cliff; NE. coast

	Depth	Colour	Fe_2O_3%	$CaCO_3$%	Organic matter %	NaCl	pH
A1	10″	Dark Grey	0·05	—	1·2	0·02	4·4
A1	22″	Grey	0·04	—	0·14	0·006	4·4
A2	28″	White	0·08	—	0·15	0·004	5·5–6
B	55″	Red-ochre	0·30	0·2	0·22	0·007	7·0
C	84″	Yellow	0·16	0·2	0·09	0·006	8·0

(NaCl: 0·03 is high, 0·003 normal)

The appearance of the profile is correlated with the height of the dune above sea level, which latter is approximately the level of the fresh water table. When the dune has become stabilized at more than 12 ft above sea level the podsol is ill-defined; the A1 horizon is deep (15″) and grades slowly into the grey-white leached layer which is about the same width. The B horizon is not sharply demarcated from either A or C; it is very deep and although the colour is reddish-brown, especially in the vertical channels, the material is not compacted. There is a deep C horizon containing tree roots above the water table.

When the dune has become stabilized at only a few feet above the water table, the profile is typically more podsolic. The grey zone (A1) is less deep (5-12″), the leached zone (A2) is deeper (25″) and whiter, and there is sharp transition to the narrow B horizon (6-10″). This is coffee coloured and somewhat compacted. Such variations in profile may occur within a few yards, but they are not reflected in any obvious differences in the vegetation. In three places on the island, only a few feet above sea level, the B horizon is a definite consolidated pan, that in dry weather can only be broken with difficulty by pick or spade. Here, and here only, the dune woodland is replaced by a well-defined heath woodland.

The dune woodland is certainly the oldest stage of the primary succession on the dune ridges, but we are not convinced that it is the climax association. There are indications of a trend towards heath woodland.

Terrace Woodland

On the N. side of all the main dune ridges on Sunday I. there are clearly defined, sandy terraces between the dunes or between dunes and the salt swamps. There is a similar but very narrow terrace on the NE. of the Drum and on the central parts of the small Robert and Gunhammer I. (Fig. 1). The main N. terrace of Sunday I. is up to 3/4 m. wide. For the greater part, these terraces are flat and aerial photographs show clearly that they are not part of the dune system, although there is a gradual transition between them and dunes proper. Their surfaces are up to 4 ft. above high tide level, and they carry what we have called the terrace woodland (Pl. V, fig. 3). On the N. sides, where they adjoin the highest and possibly the climax stage of the salt marsh succession (*Melaleuca ericifolia* scrub), there is usually a clear and steep drop in ground level of about one foot—probably due to wave action at the highest tides.

The vegetation of these sandy terraces resembles that of dune woodland; the dominant tree is *Eucalyptus viminalis*, and the dominant species of the ground flora is bracken. *Banksia serrata* is far less frequent and is absent from much of the terrace woodland. Moreover, the ground flora is much poorer in species (especially woody species) than that of the dune woodland. *Lepidosperma concavum* and the numerous xeromorphic shrubs are rare. Instead there occur such species as *Lomandra longifolia, Scirpus nodosus, Hydrocotyle hirta, Pelargonium australe, Senecio lautus, S. glomeratus, Gnaphalium candidissimum, Agrostis avenacea* and, locally, in the damper areas, *Gahnia sieberiana, Leptocarpus tenax, Juncus pallidus*. There is little doubt that grazing has been more intensive on the terrace than on the dunes, and this is reflected in the presence of alien species, such as *Cirsum vulgare, Holcus lanatus, Cerastium glomeratum, Plantago coronopus*. There are extensive areas of the terraces which are badly drained and in which woodland is replaced by freshwater swamps or open pools.

The surface layers of the soil in the better areas are acid (pH 5·5), of a dark grey sand and there is a slightly podsolic profile. The A horizon is grey or brown, never white. The B horizon is darker brown, very slightly compacted, usually at 16″ below the surface and very ill-defined. The C horizon is an uncompacted, yellow-brown sand showing irregular mottling at 3-4 ft where water lies in summer. There is very little clay or silt in the first 3 ft of the horizon, and generally the soil profile resembles that of the dune woodland but appears less mature. It is underlain at 3-4 ft by marine clays with shells, and there is no evidence of the existence of old clay- or peaty-soils resembling those of the salt marshes. For this reason we abandoned an initial hypothesis that the terraces were derived from salt marshes. As indicated in our section on the physiography, we still believe that these terraces were formed either by an uplift of the land or by a fall in sea level (Fig. 2), but we conclude that they were originally sandy, unvegetated flats exposed only at low tide. Aerial photographs show that such a low-flying flat exists at present on the landward side of Clonmel. Leaching has been less pronounced than in the older and higher dune ridges. The vegetation today resembles that of Zone 5 of the dune succession, but is poorer in species, especially those which are indicative of a trend to heath woodland. The early stages of plant succession on the terraces can only be surmised, although it is perhaps significant that the central terrace of Gunhammer I. carries tall *Leptospermum laevigatum* instead of *E. viminalis*.

Heath Woodland

One of the more interesting features of Sunday I. is the existence, admittedly in small areas only, of a damp heath woodland community. The best example occupies 2 or 3 acres in the SW. of the island (Fig. 3, site A). Other examples were located at sites B and C, but these had been recently burned and they will not be described in detail.

A species list (Table 1) does not, by itself, bring out the very striking difference in the aspect of heath woodland and the dune woodland (Pl. V, fig. 1, 4). In both communities the co-dominant trees are *Banksia serrata* and *Eucalyptus viminalis*, which do not form a closed canopy. The heath woodland is immediately recognised by the dominance of *Leptospermum juniperinum* in the shrub layer, the almost complete absence of *Pteridium* and the greater abundance of xeromorphic shrubs. At site A these are mainly *Hibbertia acicularis, Acacia verticillata, Amperea xiphoclada, Acrotriche serrulata* and *Astroloma humifusum*. In addition there are the characteristic heathland species *Euphrasia collina, Xanthorrhoea minor, X. australis, Calorophus lateriflora* and 2 other species, *Casuarina pusilla* and *Banksia marginata*, which, as far as we could ascertain by extensive search, are restricted to the heath woodland and occur nowhere else on the island.

The community at A is typical of the widespread, damp heath woodland of Victoria, although it lacks some of the characteristic species generally present in the more extensive mainland examples, including some species which are present but infrequent in Zone 5 of the island dune succession. The 3 sites (Fig. 3, A, B, C) were all similar in being confined to low-lying parts of the island and in having a highly podsolized soil profile with a true hard-pan ('coffee rock') in the B horizon. In winter the waterlogged pan is fairly easily cut with a spade, but in summer a pick is required to break through it. It has already been pointed out that the B horizon of the dune woodland varies a good deal in its width and compactness. In most of the lower parts of the dunes, where the B horizon must have developed near the winter water table, it is narrow, obvious and compacted, but never rock-like. In higher dunes, this horizon is deeper, much wider and hardly compacted at all. Only in those few places where the B horizon has become hard and rock-like is there a characteristic heath woodland developed.

Numerous soil pits were examined in various parts of the island before this conclusion was reached. 13 of them were dug along the line transects leading out from the heath at A (Fig. 3) to the nearby dune woodland and marsh. All pits dug in the heath woodland or on its extreme margin showed the existence of a hard pan at a depth of about 26". Only a few feet outside this margin there was slight concretion but no continuous hard pan. Within 100 yds of, and outside the heath margin, in *Eucalyptus* woodland with bracken, and in a marshy area with *Gahnia* and *Leptospermum juniperinum* but no typical heath plants, there was leaching and some deposition between 10" and 30", but the B horizon in all these places was not compacted and was lighter in colour than the 'coffee rock'. Well-marked hard pan was found in the profiles under sites B and C.

In the heath soils investigated the pH range in the profile was from 4 (A horizon) to 5 (C horizon). As shown in Table 3, the typical dune woodland soil is only slightly less acid in the surface layers (pH 4·5), but ranges to pH 8 in the deeper layers of the C horizon. There are also undoubted differences in soil fertility between heath and dune soils. Tomato seedlings were grown in surface samples of both soils, each with a pH of between 4 and 4·5. Those in the heath soil

developed very poor root systems and had thinner stems than the others. The growth in height was poor in both tests, but after some weeks the plants of the heath soils had a mean height of only half that of the other set (9·4/18.2″), the difference being statistically significant. There seems little doubt that the heath soils are much more heavily leached than those of the dune woodland.

It is impossible to decide whether the 3 small areas of heath woodland on Sunday I. are derived, after extensive leaching, from low-lying dune woodland or from terrace woodland. All 3 sites are on the boundaries where the 2 communities meet (Fig. 3). A levelling survey showed that at site A the soil surface is 2 ft above high water mark. On its E. side it is bounded by dune woodland rising to 8 ft above high water mark. On its W. side it adjoined one of the treeless and more swampy parts of the terraces. Sites B and C, both damaged by fire, are also low-lying areas adjacent to both dune and terrace. The only reason for assuming that heath woodland is more closely related in origin to the dune succession is the fact that heath species occur sparingly in dune woodland but are absent from terrace woodland.

Elsewhere we shall discuss the possibility that dry heath woodland and dry heath are climax communities of the coastal dune succession, but with *Leptospermum myrsinoides* rather than *L. juniperinum* as a dominant shrub. The former species is very rare on Sunday I. and, although it occurs, with a number of other heathland species in the E. dune ridges, a thorough search has failed to reveal the existence of even tiny patches of heath woodland or of treeless heath on the higher dunes. In view of the relatively light and sporadic incidence of fire on the island, and the fire-resistant properties of the heath species, it appears to us most unlikely that this absence of dry heathland today is due to its destruction by fire and competition by bracken. The soil profile throughout Zone 5 of the dune sere is markedly less leached, and the B horizon less well developed than is usual in Victorian heathlands. We conclude that the dunes on Sunday I. are not yet old enough to develop a heath vegetation, except in those low-lying regions (at sites A, B and C) with a high and variable water table, where leaching has been severe.

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References

Davies, J. L., 1957. The importance of cut and fill in the development of sand beach ridges. *Aust. J. Sci.* 20: 105-111.

Thornthwaite, C. W., 1948. An approach towards a rational classification of climate. *Geogr. Review* 38: 55-94.

Explanation of Plates

Plate IV

Fig. 1—Zone 1, Clonmel. Embryonic dune, sand-binding by *Festuca littoralis*. The berm is seen in the background with the early stages of new embryonic dunes.

Fig. 2—Zones 1-3, Clonmel. Fore dune in foreground, with *Spinifex* runners. *Acacia* invading from Zone 3 on R. Embryonic dunes in background.
Fig. 3—Zones 2 and 3, Clonmel. *Spinifex* on fore dune with *Acacia* invading from Zone 3, R.
Fig. 4—Zones 2 and 3, Clonmel. View over fore dune to dune scrub. *Spinifex* in foreground. In background, closed dune scrub with *Acacia*, *Olearia* and *Helichrysum*.

PLATE V

Fig. 1—Zone 5, Sunday I. Typical dune woodland on SW. ridge near the settlement. *E. viminalis* with *Banksia serrata* on R. *Ground* flora dominated by *Pteridium* and *Lepidosperma concavum*. Scattered shrubs of *Monotoca* are visible.
Fig. 2—Zone 5, Sunday I. Typical soil profile of dune woodland. The vertical ruler is 2 ft long. Leached horizon (A_2) obvious. B horizon wide and diffuse with vertical pipes. Note secondary deposition of sand above the dark A_1 horizon.
Fig. 3—Terrace woodland, Sunday I. Flat terrace on N. coast, with *Pteridium* and *E. viminalis*, partly cleared in foreground.
Fig. 4—Heath woodland, Sunday I. Site A Fig. 3, showing tall unburnt *Leptospermum juniperinum* the dominant shrub with *B. serrata* R, L, middle foreground, *E. viminalis* back centre. *Pteridium* almost absent but one frond shows in centre foreground.